International Journal of Aquatic Biology (2013) 1(6): 306-315
ISSN: 2322-5270
Journal homepage: www.NPAJournals.com

Original Article

Use of minimum legal size in managing black clam (*Villorita cyprinoides*) fishery in India

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Abstract: Using size at first maturity (SFM) as a biological reference point, the minimum legal size (MLS) for the black clam, *Villorita cyprinoides* was fixed at 20 mm. Corresponding minimum legal weight was calculated as 3.4 g. The reproductive load and mean generation time were determined as 0.35 and 0.72, respectively. Of the total quantity of clams exploited during 1996-97, 50% were juveniles. The percentage was reduced to 7.9% during 2009-10. The loss in harvest weights due to exploitation of juvenile clam was 50%, 23% and 37% and the economic loss caused was US$ 4.6 million, US$ 1.5 million and US$ 1.1 million for the periods 1996-97, 2000-01 and 2002-03, respectively. If the undersized clams were permitted to grow up to MLS, the harvest weights could have improved by up to 24% and hence the economic gain is to the tune of US$ 1.40 million during 2009-10. The difference between the present L_{mean} in the fishery and the L_{opt} is 4 mm.

Article history:
Received 12 July 2013
Accepted 4 December 2013
Available online 25 December 2013

Keywords:
Economic loss
Juvenile exploitation
Minimum legal size
Size at first maturity

Introduction

The State of Kerala leads India in the production of clams with estimated annual landings of about 66,000 tonnes in 2008-09. The black clam, *Villorita cyprinoides* (Family Corbiculidae) contributes 45,000 tonnes, or about two-thirds of this total (CMFRI, 2009; Narasimham et al., 1993). During 2009-10, India exported 560 tonnes of clam meat in frozen, dried, freeze-dried and cooked forms, earning a foreign exchange of US$ 1 million (MPEDA, 2010). Most of the annual production of black clams, about 25,000 tonnes, comes from Vembanad Lake where almost 4,000 fishermen harvest them.

The Lake holds large sub-fossil deposits of black clam shells that are mined for commercial use (Kripa et al., 2004). The other clams harvested in the lake are the grey clam, *Meretrix casta*, and to a much lesser extent, the yellow clam, *Paphia malabarica*, and another, the *Sunetta scripta*. The lake also has commercially-important finfish. The fisheries for the clams and the finfish provide the major livelihood for coastal communities around the lake (Sathiadhas et al., 2004). Being a rich and cheap protein source, clams are regularly fished from Vembanad Lake and the meat is sold in local as well as export markets for consumption. Besides, the shell also holds commercial importance being the raw material for the manufacture of cement, calcium carbide and sand lime bricks. They are also used for lime burning, for construction, in paddy field / fish farms for neutralizing acid soil and as slaked lime. The shell is used as a raw material for the manufacture of distemper, glass, rayon, paper and sugar.

Harvesting of the black clams continues throughout the year (Kripa et al., 2004). Each fisherman harvests black clams about 20 days a month. Harvesting method is using a hand rake with a pole attached ("kolli" or "varandi") and dragging it on the bottom while the fisherman standing in his canoe. The pole is one inch in diameter and made of iron. The clam fishermen are organized into professional societies.

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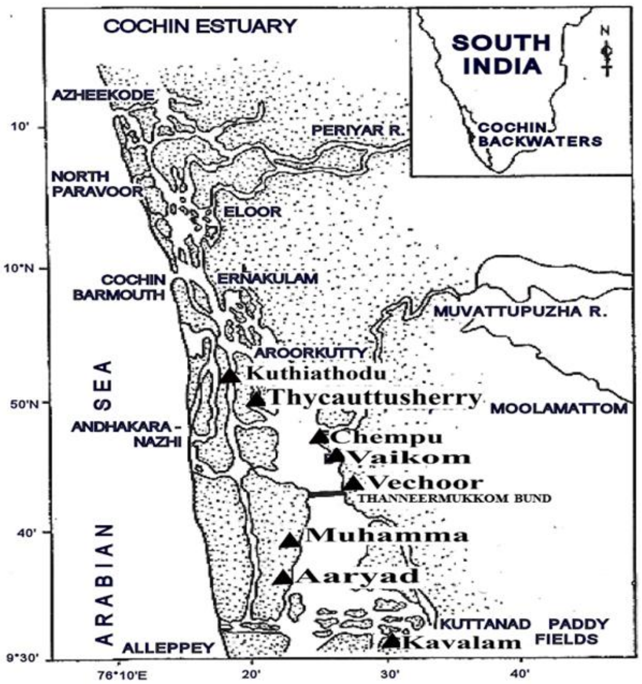

Figure 1. Map of Vembanad Lake with the major harvesting locations of *V. cyprinoides*.

There are eight black clam societies distributed around the lake in the Kottayam and Alappuzha districts (Fig. 1). Fishing rights and licenses for harvesting in the lake are issued by the State Department of Mining and Geology. The total harvesting area leased out to the societies comprises about 18.65 km² (Laxmilatha and Appukuttan, 2002). The societies handle the sales of the clam shells by purchasing from the fishermen at a rate of US$ 13-15/ton. Each fisherman and his family produce about 14 kg of meat and 130-140 kg of shells on his best harvesting days. Fishermen's wives usually sell the meat. Meat is sold in the local village door-to-door, where customers prepare them to include as an important component in their evening meal for its high nutritional value. Agents sometimes collect the meats directly from the fishing villages and sell them to retail food markets and large restaurants. The larger the meat is the higher the price. A kilogram of large meat brings about US$ 0.88. Fishermen receive US$ 0.11-0.22/kg for the juvenile clam meat.

An increasing price in the meat and shell of hard clams drove substantial jumps in fishing effort. In order to harvest more and more clams from the lake, modifications to the fishing gear, especially in the mesh size of the net was applied. Considerable amounts of juvenile black clam are exploited every year from Vembanad Lake, which results in economic loss, in terms of harvest weights. Earlier, the mesh size of the hand rake was 30 mm or above and it has been noticed that now fishing is done with hand rakes of mesh size 20 mm or below. The situation recalls a report on the juvenile fish capture in India by using trawls of mesh size less than 35 mm. Najmudeen and Sathiadas (2008) estimated the economic loss due to juvenile fishing in India by trawls as US$ 15.84 billion. A similar study on the cephalopods such as *Loligo duvauceli*, *Sepia pharaonis* and *Octopus membranaceous* reported that the quantity of juvenile exploited from India by small meshed trawl fishing was 1817 tonnes, 2281 tonnes and 527 tonnes, respectively (Mohamed et al., 2009).

Good fisheries management generally requires that fishing gears retain large fishes while allowing juveniles to escape (Armstrong et al., 1990). This also avoids recruitment over fishing by allowing animals to spawn at least once before becoming vulnerable to capture. Growth over fishing occurs when the fishery targets fishes of a size below the optimal harvestable size. When the fishes are removed before the cohort has had the opportunity to achieve its maximum biomass level, the fishery will lose much of the potential yield that could be achieved by catching them in the near future. Disproportionately large scale removal and destruction of young and juveniles of fishes are detrimental to the fishery because when juvenile mortality is increased the future catches and subsequent recruitment will be affected (Crowder and Murawski, 1998; Diamond et al., 1999). Exploitation of juveniles of commercially important species results in considerable economic loss, in terms of what could have been obtained had the fishermen waited for a few months and allowed the animal to grow in size and weight. Although, this phenomenon called as growth over-fishing has been reported in many works (Pauly, 1988), assessments of economic loss due to such fishing are few (Najmudeen and Sathiadhas, 2008). Concerns about over fishing rarely enter into management plans for invertebrate fisheries, especially those for bivalve mollusks (Hancock, 1973). The rationale used to support exclusion of stock-recruit relationships from management plans for bivalve and other invertebrates is based on their high fecundity, long larval period and widely dispersed adult distribution. Yet, management of most bivalve fisheries worldwide assumes that high fecundity will sustain historic levels of recruitment without need to protect (Jamieson, 1993).

A minimum legal size (MLS) is seen as a fisheries management tool with the ability to protect juvenile fish, maintain spawning stocks and control the sizes of fish caught. The MLS sets the smallest size at which a particular species can be legally retained if caught (Hill, 1992) and in doing so helps to regulate the average age at first capture (Walker, 1992). Winstanley (1992) suggested that a MLS could be used to protect immature fish ensuring that enough fish survive to spawn, control the numbers and sizes of fish landed, maximize marketing and economic benefits, and promote the aesthetic value of fish. The ICES advisory committee on fisheries management recommended that fishing gears should retain only 25% of the fish at the minimum legal size (Reeves et al., 1992). Altering the selectivity of fishing gears (i.e. changing minimum mesh sizes) can play a crucial role in reducing the numbers of fish caught below the MLS, and thus the selectivity of fishing gears must be considered alongside any potential MLS.

Besides juvenile exploitation, the black clam fishery of Vembanad Lake is further affected by externalities like excessive fishing pressure, inflow of pollutants, shallow water industrial activities etc. all of which challenge the very sustainability of black clam resources and livelihood securities of black clam fishermen. Hence, This study aims to quantify the amount of juvenile black clams exploited by hand rake from Vembanad Lake and arrive at minimum legal sizes for the black clam. In addition, an assessment on the economic loss to the fishermen by exploitation of these juvenile black clams is attempted. Here we exploit long term data sets for black clam harvest to test whether the fishery changed over a two decade period characterized by greatly increased harvest pressure and declining clam stocks.

Materials and Methods

Study area: The Vembanad Lake (9°44.34'N and 76°24.87'E) is the largest brackish water lake on the west coast of India. Narrow and sinuous in the north and much broader in the south, the lake parallels the coast of the Arabian Sea. It is 96 km long and 14 km wide at its widest point and has a surface area of 24,000 km^2. It consists of estuaries, lagoons, some man-made canals, marshes, and mangroves (Ravindran et al., 2006). The salinity ranges from 0.3 at the lower end of the southern part to 18 ppt near the inlets. The water temperature ranges from 26 to 33.5 °C. Aside from some shipping channels that are maintained to a 10-13 m depth, the major portion of the lake has a depth range of 2-7 m (Menon et al., 2000). Two major rivers, the Pamba and the Periyar, and four smaller rivers that all originate in the Sahya Mountains to the east, flow into the lake. The lake opens to the Arabian Sea through in two locations, one at Azheekode, that is at least 100 m wide and fairly deep, and the other at Cochin Gut that is 450 m wide (Menon et al., 2000). At the two openings, the rise and fall of tide is from 0.6 to 0.9 m. The bottom sediments where the black clams occur are a mixture of fine sand, clay, and silt and they extend over wide areas. Broad wetlands surround the lake. They are included in the wetlands of international importance, as defined by the Ramsar Convention for the Conservation and Sustainable Utilization of Wetlands in 2002, in part because they support more than 20,000 waterfowl in the winter.

Kerala has a tropical climate with two rainy seasons, the heavy southwest monsoon from June to September and the lighter northeast monsoon from October to November. The total annual rainfall is about 300 cm. The maximum water temperature, at least 30 ^{o}C, occurs during pre-monsoon and the minimum is 24 ^{o}C which occurs in August (Ravindran et al., 2006). During the monsoon, the flood discharge from the rivers can reach 2,500 m^3/s (Ravindran et al., 2006). Outside of the monsoons, the weather is dry and winds are light. Known for its scenic beauty, the Vembanad Lake and surroundings attracts many tourists.

The lake has both brackish and nearly freshwater environments. They are separated from each other by a man-made bund or barrier, the Thanneermukkom, which runs across the middle of the lake. Constructed in 1974 and functional since 1976, it is about 2 km long. The government keeps it open to allow brackish water to flow to the southern part of the lake for six months, but then closes it for six months, December to May each year. Its purpose is to prevent the entry of substantial amounts of salt water to the southern area because it used to reduce the production of rice in paddy fields off the southeast side of the lake. The paddy fields are extensive, totaling about 20200 ha in area. When the water remains fresh or nearly fresh (less than 0.5 ppt), two crops of rice can be produced each year. In some of the lowest land areas in this part of the lake, rice is grown for half a year for one crop, and then shrimp are grown in the same location for half a year. The shrimp larvae swim into the areas during the highest tides and remain to feed and grow to harvestable sizes. However, the black clams cannot reproduce well in low salinity and large areas in this southern region, otherwise suitable for the clams, cannot support them now. Also, the average size of the black clams has diminished. In the northern region, salinities from 8 to 18 ppt are usual in March to May but the water salinity can be as low as 0 ppt during the monsoon.

The floodwaters during the monsoon rains carry silt and clay into the lake. Especially in the southern section of the lake, live black clams in some habitats have been buried by the sediments. Over the centuries, this annual process has led to the accumulation of large deposits of black clam shells. The shells, black when the clams are alive, become white after being buried. The deposits are found varying in thickness from 22 to 50 mm and are under a sediment burden of 20 to 60 mm. The shells are also found under some lands that surround parts of the lake including the rice paddy fields. This shows that the lands were once part of the lake, but were covered by sediments (Rasalam and Sebastian, 1976).

Data: Clam production data sets were collected from Central Marine Fisheries Research Institute (CMFRI). These data sets were provided by the eight different black clam co-operative societies for the periods 1996-97, 2001-02, 2002-03 and 2009-10. The societies keep accounts of the daily harvest by the respective licensed clam fishermen of the different localities surrounding Vembanad Lake. This accounted the annual production data of black clam from Vembanad Lake. Cost details for the respective years were also obtained from the societies. The length frequency data sets for these years were obtained by sampling the clams from the landings at eight stations. Monthly sampling of 200 clams from each landing locality of eight societies was done and they were measured for their length along the anterior – posterior axis and was recorded to the nearest of 0.1 mm using digital vernier calipers.

Analysis: To determine the proportion of juveniles exploited, the size at transition from juveniles to adult has to be determined. The method used to decide this was by plotting size-wise percentage of mature clams and determining the size at first maturity (SFM- size at which 50% of the animals are mature). SFM was considered as the size of transition from juvenile to adult and was taken as the cut-off length for fixing the MLS. In doing so, it is assumed that most animals in the population would have an opportunity to become mature and spawn without prejudice to the selection factor of the gear. The weight corresponding to MLS is the minimum legal weights (MLW). This was determined by converting MLS into MLW using the standard L-W relationships. The asymptotic length (L_∞) and

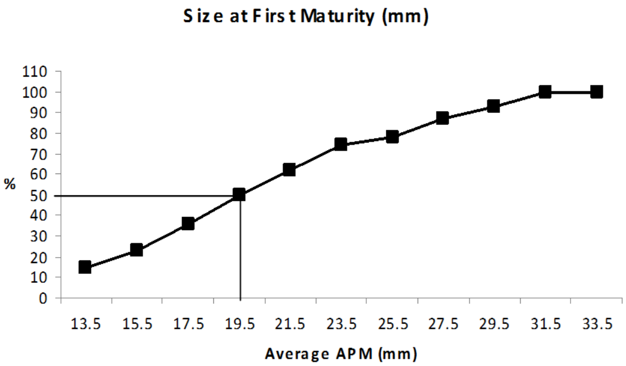

Figure 2. Size at first maturity of *V. cyprinoides*.

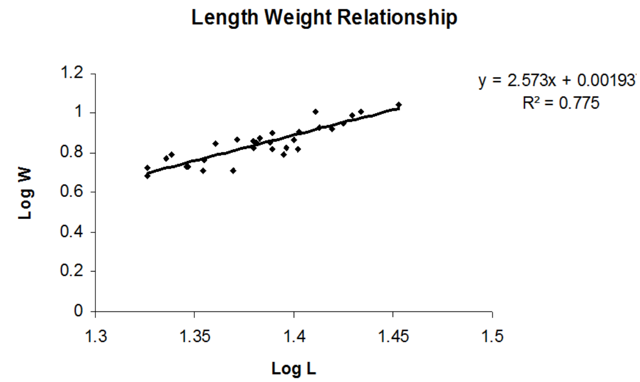

Figure 3. Length-weight relationship of *V. cyprinoides*.

growth rate (K) were estimated using length frequency analysis (ELEFAN). These were taken as input parameters to determine the optimum length of capture (L_{opt}) and mean generation time (t_g). The reproductive load, which is the ratio between SFM and L_∞, was determined to gain insight into the relationship between growth and reproduction of these animals (Freose and Pauly, 2000). The economic loss due to the capture of juveniles was estimated for each year by considering the price of adult and juvenile for that particular year and loss in harvested weights of juveniles if they were permitted to grow up to MLS.

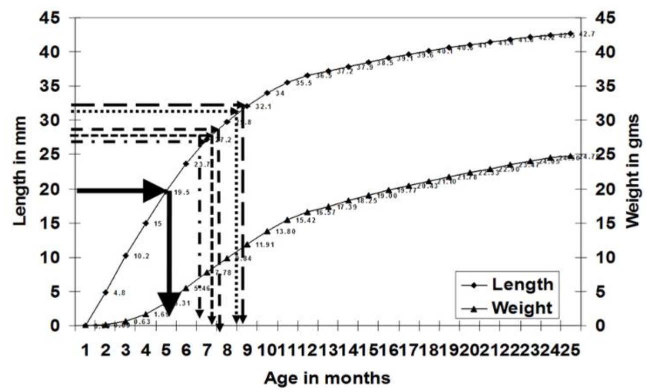

Figure 4. Age – length - weight key of *V. cyprinoides*.

Results

The annual production data (in tonnes) with corresponding mid length (minimum mid length: 13.5 mm and maximum mid length: 46.5 mm) for different years is given in Table 1. The smallest size at which both males and females of black clam mature (SFM) is 20 mm (Fig. 2).Using SFM as a biological reference point, the MLS for the black clam was fixed at 20 mm. Corresponding weight, MLW was calculated as 3.4 g (Fig. 3). The growth parameters L_∞ and K were estimated as 56.2 mm and 0.935, respectively. L_{opt} was determined as 28.05 mm (Fig. 4). The L_{opt} value is 50% of L_∞. The reproductive load and mean generation time were determined as 0.35 and 0.72 respectively. L_{mean} for the four year classes are given in Table 2. The difference between the present L_{mean} in the fishery and the L_{opt} is 4 mm. Of the total quantity of clams exploited during 1996-97, 50% were below MLS. The percentage was reduced to 7.9% during 2009-10 (Table 3). The loss in harvest weights due to exploitation of juvenile clam was 50%, 23% and 37% and the economic loss caused was US$ 4.6 million, US$ 1.5 million and US$ 1.1 million for the periods 1996-97, 2000-01 and 2002-03, respectively. If the undersized clams were permitted to grow up to MLS, the harvest weights could have improved by up to 24% and hence the economic gain is to the tune of US$ 1.40 million during 2009-10. However, it is evident that the economic loss has come down over a period of 14 years.

Discussion

In many of the developed countries, much of the non- targeted catches and juveniles are discarded in the water, whereas, in the developing countries, the non-targeted catches and under sized fishes are also brought to the shore. Marine fishing in India has been contributing significantly to the country's macro-economic standards and the coastal livelihood security. The analysis of costs and

Table 1. Length class wise average harvest weights (in tonnes) of *V. cyprinoides* from Vembanad Lake during 1996-1997, 2000-2001, 2002-2003 and 09-2010. Horizontal line indicates the set MLS.

Mid length (mm)	1996-97	2000-01	2002-03	2009-10
13.5	153.358	486.4		
14.5	439.89	190.57		
15.5	3239.02	345.38	451	212
16.5	3694.99	1338.64	195	359
17.5	4988.51	1411.87	1022	414
18.5	4309.57	1226	1005	1806
19.5	**2033.33**	**1087**	**1287**	**1009**
20.5	1637.38	1192.22	2419	1006
21.5	1517.84	522.26	1127	1610
22.5	1780.44	1029.71	1710	2524
23.5	1354.95	1362.59	935	2411
24.5	2137.75	2406.86	136	2408
25.5	630.78	2922.12	442	2302
26.5	535.44	3238.01	682	2341
27.5	259.41	2552.56	817	2265
28.5	1546.34	761.98	951	2217
29.5	900.4	877.79	559	1169
30.5	1696.75	914.39	855	2258
31.5	831.7	1772.24	1279	2624
32.5	554.44	2190.55	421	2516
33.5		816.74	718	3623
34.5	1560.7	377.78	824	2478
35.5		314.08		2025
36.5		872.6	505	2156
37.5		448.63	203	2036
38.5		496.74	448	1652
39.5				
40.5				672
41.5				
42.5	743.19		500	414
43.5	626.78			745
44.5				251
45.5				141
46.5				
Total	37173	31156	19490	47644
Juvenile clam meat	18858	6085	3960	3800
Adult clam meat	18315	25071	15530	43844

Table 2. L_{mean} values for the four year classes of *V. cyprinoides*.

Year	L_{mean} (mm APM) in fishery
1996	27
2000	29
2002	31
2009	32
L_{opt} was calculated as 28.05 mm APM	

earnings of the numerous crafts and gears along the Indian coast reveals the economic importance and strength of the fishery sector. Though literature is available on the economic implications of by-catch, juvenile proportion of economically important fishes has not been quantified in most of the studies done in other countries which have addressed the destructive fishing behavior of different crafts and gears (Najmudeen and Sathiadhas, 2008). There is an interesting debate on the utilization of by-catch or

Table 3. Year wise quantity (tones) and price of juvenile and adult *V. cyprinoides* meat (US$/Kg) and the calculated economic loss (in US$) if the juveniles were allowed to grow.

Year	Quantity of juvenile clam meat exploited (in Kg)	Value obtained for juvenile clam meat exploited* (in US$)	Quantity of adult clam meat exploited (in Kg)	Value obtained for adult clam meat exploited** (in US$)	Value that might have obtained if the juveniles were allowed to grow (in US$)	Economic loss due to juvenile clam harvest (in Us$)	Percentage of juvenile clam exploited
1996-97	18858000	1532174	18315000	6128697	6128696.78	4596523	50.73
2000-01	6085000	791030.2	25071000	2274212	2274211.89	1483182	19.53
2002-03	3960000	514787.1	15530000	1608710	1608709.78	1093923	18.92
2009-10	3800000	617484.6	43844000	2274943	2274943	1234969	7.98

*Unit price of juvenile clam meat remained static as Us$ 0.0812/Kg during 1996-2010.
**Unit price of adult clam meat
1996-97: Us$ 0.325/Kg
2000-01: Us$ 0.374 /Kg
2002-03: US$ 0.406/Kg
2009-10: US$ 0.487/Kg

juvenile fishes landed as this would affect the long-term conservational measures of the fisheries (Clucas, 1997). Peterson (2002) opined that changes in hard clam management in North Carolina and elsewhere throughout the species' range and for bivalve fisheries generally are important to achieve sustainability.

Most studies use SFM as a reference point to differentiate between juveniles and adults. However, this is fraught with the error of including a substantial portion of adults as juveniles. Indeed, when the objective is protection of juveniles and prevention of growth over-fishing, SFM is an apt matrix to fix MLS. MLS has the advantage of being relatively simple to understand (Hill, 1992). It also has the capacity to reduce such problems as recruitment over-fishing by allowing fish to spawn once before being vulnerable to capture. In this study, the proportion of juveniles was observed to decrease from 1996-97 to 2009-10. This augers well for the fishery, although the exact reasons for it are unclear, particularly when effort expanded has increased over the years. A decrease in the juvenile exploitation over the years show that clam fishermen of Vembanad lake are increasingly aware of the negative impact of growth over-fishing. They are organized under eight different black clam societies and are vocal and proactive in issues related to clam fisheries and sustainability. In some areas, the clam fishermen restock the juvenile clams back into the lake for further growth and future harvest.

Minimum legal sizes have been used as an effective fisheries management tool for more than 100 years with the chosen sizes being reviewed, but not always changed, from time to time. The purpose for setting legal sizes in Australia was reviewed by Hancock (1990) and he found protection of immature animals or juveniles and allowing individuals to spawn at least once as the chief reasons. Control of fishing until optimum market size was cited next in importance, followed closely by the objective of controlling harvesting. In Australia, the total usage of minimum legal sizes involves 125 species (Hancock, 1990). In India, minimum legal weight (MLW) has been officially notified for export only for the very valuable rock lobsters, based on SFM (Radhakrishnan et al., 2005). In most cases the fixation of MLS appears to be based on empirical information and in some cases on specific scientific studies on the SFM. Setting a MLS and implementing the same would increase the economic efficiency of the fishery, besides affording protection to juveniles, allowing them to grow in weight and length. The present study shows that if the undersized clams were allowed to grow up to MLS, the harvest weights could have improved by up to 24% in 2009-10 and would result in higher income. The economic advantage of preventing growth over-fishing in black clam is very clear from this study. Such a conclusion was also brought out by Najmudeen and Sathiadhas (2008). However these authors estimated the losses using SFM as the criteria to differentiate between juveniles and adults. In tropical waters, where growth and maturity in fishes is relatively faster, fishes mature at very small sizes, as evident from the very low reproductive loads. In fishes, generally the reproductive load values range between 0.4 and 0.7 with higher values being characteristic of smaller fishes (Froese and Pauly, 2000). It is very apparent that the reproductive loads in the present study are comparatively very low indicating their resilience to high fishing pressure and their relative success in the ecosystem. While bivalve mollusk fisheries and those for marine invertebrates more generally, are seldom managed to conserve spawning stock biomass, there is accumulating evidence to suggest that marine invertebrates can suffer recruitment limitation despite their high fecundity and complex life cycle.

Since fishing is an economic activity, the species that fishers target, the level of exploitation and the gear that they use are all influenced by the benefits they receive (i.e., the revenue) and the costs they incur (Pascoe, 2006). As the immediate benefits from the juvenile fishing by destructive gears in India are lucrative, the fishermen will be more adherent to use such gears unless strict regulations are imposed on them with proper monitoring of their implementation. If the fishermen realize that there is no chance of getting economic incentives for undersized clams, he would not waste his effort by catching juveniles. Clucas (1997), while discussing some of the critical points relevant to this issue, highlighted the importance of conserving marine resources than just utilizing everything that is caught. While fishing, when the fishermen realize that the catch contains higher percentage of juveniles, they would try to change the fishing ground and migrate to other places where more percentage of bigger clams is available.

In the seas, adjacent to the British Isles, demersal fish are exploited mainly by various forms of trawls and seines. These gears are selective in capturing fish which enter them. Fish below some small size escape from the gear while fish above some larger size are all retained. Between the lengths of zero and total retention, the proportion retained increases along an S-shaped curve, often referred to as the selection ogive. If the length at first capture is correctly determined, the yield from the stock is optimized. (Armstrong et al., 1990). Traditional methods of fisheries management, regulating effort through gear restrictions, harvest amount, size restrictions, and seasonal openings so as to sustain spawning stock biomass of wild stocks, have proven difficult to enforce and ineffective in most fisheries (Boltsford et al., 1997).

Even though the fishermen in India have succeeded in improving the fishing efficiency with the help of technological advancements, they failed to achieve economic efficiency since huge amount of future income in the form of large quantity of juveniles are being destroyed every year (Najmudeen and Sathiadhas, 2008). Lack of linkage between institutional policies and fishery management administrators for the long-term sustainability of marine fisheries in India is another concern. For example, the fishery research institutions in the country are concentrating in developing novel value added products for the utilization of trash fishes and fishery by-catch. Utilization of by-catch provides some immediate monetary benefit to the fishermen and the processing industry. However, complete utilization of the by-catch, particularly when it is dominated by juveniles, may lead to increased pressure on some stocks of economically important species. This will eventually encourage the fishermen to target the juveniles of commercially important food fishes while fishing in shallow inshore waters.

In some fashion, managers of exploited bivalves and other marine invertebrates must reflect with their management actions the real potential for recruitment and growth overfishing. In order to conserve the black clam wealth of Vembanad lake from depletion and for regeneration and rejuvenation, the government has to implement measures similar to trawl ban (seasonal closure of mechanized trawling), which is effective enough up to a certain extend to protect the marine fishery resources of India. The MLS fixed for black clam shall become a regulatory practice, so that juvenile exploitation and economic loss due to this can be controlled. An effective gear monitoring mechanism should be implemented. Fisheries departments, research institutions and NGO's should take initiatives to conduct awareness programmes among fishermen and make them understand the threats of juvenile exploitation.

Acknowledgements

Authors wish to acknowledge The Director, CMFRI, Cochin for the facilities provided to carry out the study. The first author wishes to acknowledge the financial assistance provided by The Department of Science and Technology, Govt. of India.

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